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Investigation of nonstationary modes of atmospheric pressure needle-to-plane gas discharge and streamer propagation

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The experimental investigation of current and radiation dynamics in nonstationary atmospheric pressure needle-to-plane gas discharge in dried air, ambient air and oxygen are presented.

1. Introduction

High-pressure needle-to-plain gas discharge is investigated with the purpose of its application in plasma-chemical reactors of ozone synthesis. It is known, that at atmospheric pressure in oxygen-contained gases a various modes of discharge can be realized in the needle-to-plane electrode geometry.

Investigations of nonstationary modes of atmospheric pressure needle-to-plane gas discharge with positive potential at the needle and streamer propagation were carried out. Both oscillograms of discharge current light emission from different cross-section of the gap and for various oxygen-contained gas mixtures (dried air, ambient air, oxygen) were studied.

2. Experiment

The experimental setup is showed in fig. 1. The needle-to-plane electrode system was located in the discharge chamber (volume 1 dm^3) with controlled gas feeding. The gas pressure was an atmospheric. The positive DC voltage was applied to the needle electrode. The discharge voltage was varied from 3 to 15kV.

There was a quartz window in the chamber for registration of the discharge radiation. The light-tight shield with 1 mm slit, which disposed transverse to the discharge channel, covered quartz window of the chamber. The moving of slit along discharge gap allowed obtaining the dynamics of light emission.

The radiation from the slit was focused by a quartzy condenser on an entrance slit of monochromator and then was registered by FEM. All dynodes were shunted by high frequency capacitors for correct measuring of short light pulses.

The discharge current and FEM's signals were displayed by double-channel oscilloscope Tektronix TDS-210. The current pulse from FEM was measured on the noninductive 50 Ω resistor. The discharge current was measured by the high frequency current probe using 75 ns delay line (for compensation of time delay between FEM's current signal and a light pulse).

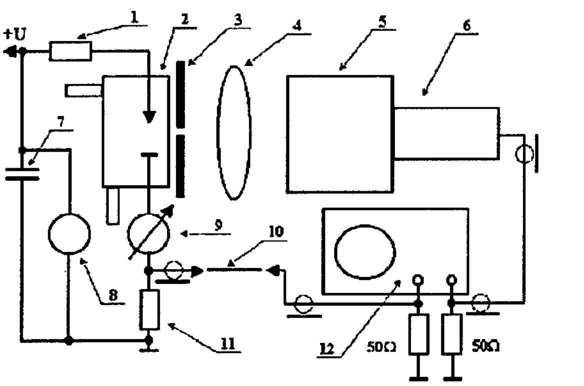

Fig. 1. Experimental setup. 1 – ballast resistor 100 кΩ, 2 – discharge chamber, 3 – shield with 1 mm slit, 4 – quartz condenser, 5 – monochromator MDR-12U, 6 - FEM-39A, 7 - capacitive filter of voltage, 8 - kilovoltmeter, 9 - microammeter, 10 – 75 ns delay line, 11 – current probe, 12 - oscilloscope Tektronix TDS-210.

3. Experimental results

The analysis of the oscillograms of a discharge current and optical signals has allowed identifying two modes of the nonstationary streamer discharge. The first mode corresponds to the case when streamers do not reach the cathode. (see osc. 1 and 2 from fig. 2). Second mode corresponds to bridging of the gap by the streamer channel (see osc. 4 and 5 from fig. 2). Section BC of the V-I characteristic in fig. 4 corresponds to first mode of streamer discharge and section CD – to the second.

The following features between the first and second modes of discharge are existed: 1) the formation and propagation of a secondary ionization wave after bridging of interelectrode gap by a streamer; 2) influence of a field emission on current dynamics and rate of streamer propagation near the cathode. Besides at mode crossover the discontinuous change of repetition frequency of current pulses was observed.

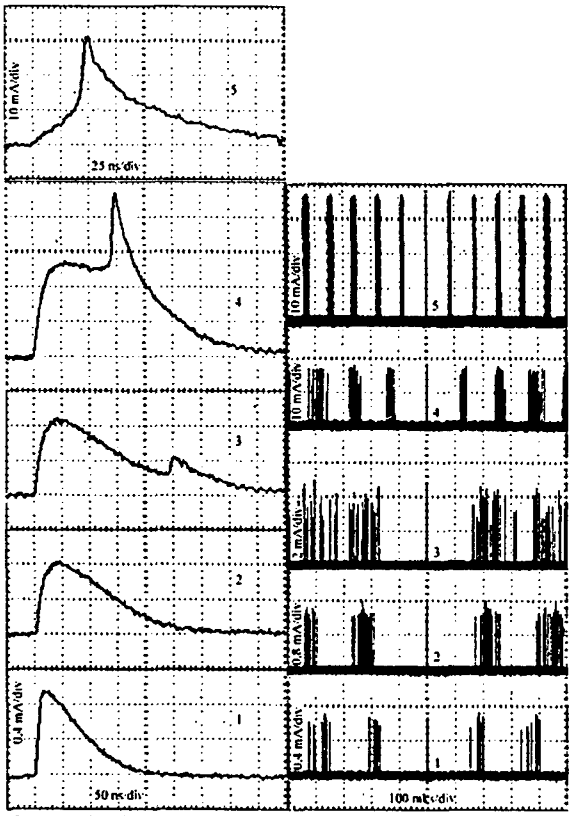

Fig. 2. Oscillograms of discharge current pulses in ambient air (interelectrode gap is 11 mm). 1 - U=4.8 kV, I_{cp}=1.5 μA; 2 - U=6 kV, I_{cp}=3.5 μA; 3 - U=6.2 kV, I_{cp}=3.8 μA; 4 - U=6.4 kV, I_{cp}=4.2 μA; 5 - U=11 kV, I_{cp}=50 μA.

The dependence of streamer propagation rate vs. location of its head in the gap was obtained from analysis of light emission dynamics. Near electrodes the streamer propagation rate increased, and in middle of the gap it decelerated.

It was noted that current pulse parameters and dynamics of streamer propagation for various oxygen-contained gas mixtures were very different. For example, the repetition frequency of streamers in oxygen was ~100 kHz, while in ambient air it was ~10 kHz).

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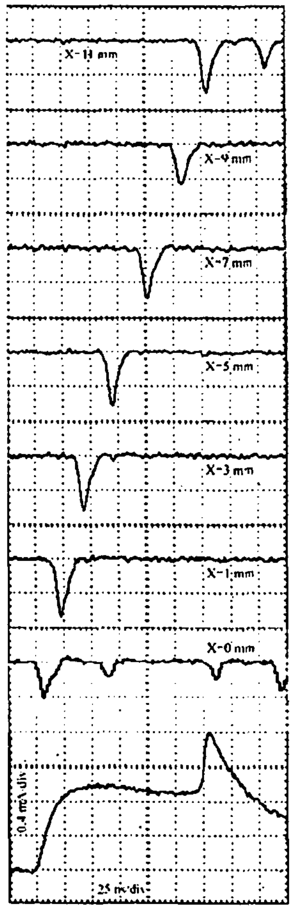

Fig. 3. Oscillograms of discharge current pulse in ambient air and FEM's current pulses from different areas of the interelectrode gap (11 mm). U=6.4 kV, I_{cp}=4.2 μA.

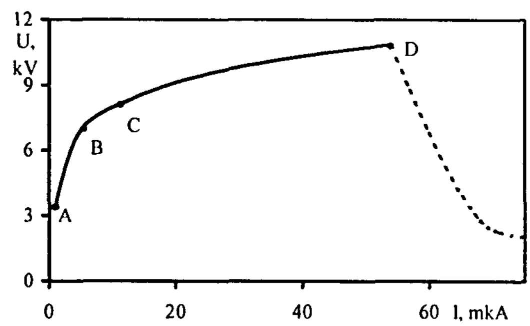

Fig. 4. The typical voltage-current characteristic of atmospheric pressure needle-to-plane gas discharge. AB – stationary mode (positive corona), BD – nonstationary streamer discharge, BC – - streamers do not reach the cathode, CD – streamer bridge the gap.